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The Policy Reaction Function of the ECB: An Ordered-Probit model

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ABSTRACT

Based on Ordered-Probit models, I estimate the monetary policy reaction function of the European Central Bank between 2001 and 2019. Results show that the ECB does display a forward-looking behaviour. Inflation and output growth projections play a significant role in their monetary policy decisions. Moreover, yield spreads across euro area countries do not seem to be significant on their decision. Therefore, the possibility of a secondary mandate related to financial markets' stability is not confirmed, according to my results. Lastly, marginal effects on the ordered-probit regressions, show that forecasts on output growth have the largest weight on monetary policy decisions.

Keywords: Ordered-Probit model, monetary policy reaction function, staff projections, yield spreads.

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1. Introduction

Earlier this year, the European Central Bank (ECB) announced a revision of its long-term monetary policy strategy. Ever since the Sovereign Debt Crisis, its ability to fulfil the mandate of price stability has been questioned, given the consistently failed approaches of bringing inflation *below, but close to two percent*. The unconventional programmes, albeit being key in guaranteeing the stability of financial markets, have not been successful in reaching the target. Curdia and Woodford (2010) questioned the true goal of credit policy in the US. Whether it is a substitute for interest-rate policy, or a non-standard measure with a different purpose than that of interest-rate policy. The same could be asked about the Assets Purchase Programmes (APP) in the euro area (EA). Are they aiming at a different mandate?

In this research I further explore the ECB's empirical reaction function using an Ordered-Probit model, as suggested by Eichengreen *et al.* (1985), Gerlach (2007), and Gerlach and Lewis (2014). For 19 years, in a total of 208 meetings, only 50 changes to the monetary policy took place, including interest rate changes and the implementation of unconventional measures. Since the ECB takes the decision of not changing rates more often than not, and for quite discrete amounts, it would be questionable to use a continuous function to describe monetary policy actions.

Besides that, since the Great Financial Crisis the ECB has broadened its toolkit, adopting *unconventional* measures such as the above-mentioned APP, a large "quantitative easing" program consisting of net purchases of corporate and government debt securities, Forward Guidance on interest rates and asset purchases, and several bank liquidity provision programs such as the Targeted Longer-Term Refinancing Operations (TLTRO). Since there is not a commonly accepted approach of converting these programmes into shadow rates, and both conventional and unconventional policy measures must be accounted for (Orphanides 2010), I focus my attention on the directional changes of monetary policy decisions.

Regarding the determinants of the empirical reaction function, research has shown that ECB's monetary policy decisions are forward-looking (Orphanides 2001). For instance, Gorter *et al*. (2010) compared two models. The traditional one proposed by Taylor, which recurs to past records of inflation and output, and a new approach, which includes, expected inflation and expected output growth. Results show that the coefficient of inflation in the more conventional model was not significantly different from zero, contrasting with the significance found in the model which included expectations.

I follow Gorter *et al.* (2010) approach, and compare the significance of inflation and output projections at different time-horizons and their effects on monetary policy actions. Since the ECB releases quarterly projections for inflation and output growth for four- and eight-quarters ahead, it is important to understand which forecasts matter the most in ECB's decisions.

In my research I also include a measure of financial integration in the euro area. Baele *et al*. (2004) defined that a market is financially integrated if all potential market participants, with the same relevant features, have equal access to the market, face the same set of rules, and are treated equally when they are active in the market. In a fully integrated market, there should not be any discrimination based solely on the location of origin. If economic agents in a monetary union do not have the same kind of credit access this can hamper central banks effectiveness in conducting an appropriate monetary policy. Therefore, financial integration is key to deliver the ECB's mandate of price stability.

While the ECB has been quite successful in promoting financial integration, and guaranteeing low spreads through EA countries, by more than doubling its balance sheet size, it has been less fortunate in achieving the two-percent inflation target. Therefore, it is reasonable to ask whether the ECB has a dual mandate concerning the stability of financial markets.

On the other hand, staff projections do not reflect these failed efforts of reaching the two-percent inflation target. Actually, ECB forecasts tend to *overpredict* inflation for several

quarters, since the Sovereign Debt Crisis. These mistakes may be the result of inconsistent forecasting models, and could potentially undermine the credibility of the Bank if not corrected.

In section 3, I provide a brief descriptive analysis on the historical behaviour of ECB's forecasting errors. Additionally, I compare its performance with that of other Central Banks.

Could Central Banks (CBs) forecasting errors be related to their mandates? Do CBs with a single mandate tend to be more optimistic on their expectations? Also, are these forecasting errors suggestive of inflation holding the largest weight in ECB's monetary policy decisions? Finally, does the ECB have a second mandate related to financial markets' stability? Or are unconventional instruments aiming solely at price stability?

My results do not support the hypothesis of a dual mandate. Coefficients on yield spreads provide no significant evidence encouraging the idea of ECB having a second mandate related to the fragmentation of the euro area. Such result may be the consequence of ECB having been reluctant in turbulent situations involving events in specific countries, such as Portugal and Italy, and not having been reluctant in others.

Additionally, I do confirm that Central Banks with a single mandate tend to be more optimistic regarding inflation projections. However, this stubbornly tendency for ECB's inflation projections to be always *below, but close to the* the two-percent target at some horizon does not mean that inflation holds the largest weight in monetary policy decisions. For instance, GDP growth projections at eight-quarters time do indeed accommodate the largest weight in ECB's decisions.

The paper is organised as follows. Section 2 provides a brief review of the related literature. Section 3 describes the historic behaviour of ECB's forecasting errors, and provides a comparison with other major CBs. Section 4 explains the data used and the methodology of the ordered probit model, which is implemented in Section 5. Section 6 concludes.

2. Literature Review

I follow Taylor (1999) in defining a monetary policy rule as a description of how the instruments of policy, such as the deposit facility rate (DFR), change in response to economic variables.

According to Taylor (1993), the short-term interest rate set by the Central Bank changes in the face of deviations of inflation from the target and the level of output relative to the trend (output gap).

However, as suggested by Eichengreen *et al*. (1985), Gerlach (2007), and Gerlach and Lewis (2014), since the interest rate remains unchanged for most of the time, and rates are often set at multiples of 25 basis points, it may be inappropriate to fit the model using OLS. Interest-rate setting follows a smoothing process, which reduces the need for consecutive changes across quarters (Gerlach 2007).

As the interest rate stands in negative territory since 2014, and is no longer the only monetary policy instrument used, it wouldn't be reasonable to evaluate the decisions of the ECB on the basis of the Taylor rule. Suggestions have been made in the sense of using a "shadow short rate" in order to quantify the monetary policy stance when interest rates reach the zero lower bound (ZLB) (Krippner 2012).

Wu and Xia (2019) proposed a Taylor rule using shadow rates (SRTR) for the Federal Reserve. The shadow rate would behave similarly to the short-term interest rate when the economy is above the ZLB, and, once the economy hits the ZLB, the shadow rate acts like a summary statistic for unconventional monetary policy. Their results indicate that the SRTR seems to be a good description of what actual happens, including the ZLB period.

McCoy and Clemens (2017) also conducted an analogous experience for the euro area. Their conclusions are less encouraging. Although they find shadow rates a useful indicator of the monetary policy stance, they believe that there is a lot of uncertainty surrounding such measure.

For instance, estimation results may differ significantly depending on the number of variables included in the model and the assumed or endogenously estimated lower bound.

This paper extends the literature on empirical reaction functions for the euro area by using an Ordered-Probit model, in which easing may either reflect a downward change in the interest rate or the introduction of a non-standard monetary instrument. More recently, Cour-Thimann and Jung (2020) also used this approach, and concluded that their Ordered-Probit reaction functions match closely the policy-makers' response over the last twenty years including the financial crisis episode. In their research, the introduction of an APP would be analogous to a 25 basis points decrease of the interest rate. Such an approach introduces a large arbitrariness into the process, and ultimately underestimates the impact of different programmes in the economy. There is certainly a perceived difference between the introduction of the first Covered Bond Purchase Programme (CBPP) which amounted to 60 billion euros, and the second CBPP which added up to 16 billion euros.

According to their empirical study, the ECB's APP delivered a greater boost to the economy than interest rate cuts would have achieved alone. However, there is no commonly accepted model/method to quantitatively compare policy rate changes and quantitative easing policies. As such, in this work I assess the central bank reaction function solely on the basis of the *directional change* of policy: tightening, no change, or easing, where in each case both conventional and unconventional monetary policy measures are considered. For example, an episode of policy "easing" could stand not only for a decrease of the interest rate, but also for the introduction of an APP.

3. Inflation & Forecasting Errors

ECB's projections for the last six years have been somewhat misguiding. Although the ECB has been having trouble in reaching the two percent inflation target, its projections indicate the exact opposite. Their forecasts have consecutively overpredicted inflation, suggesting two things. First, that the ECB has been solely focused on inflation, and, second, that it has been successful in fulfilling its single mandate of price stability.

In this section, I approach this latter consideration, providing a brief description of the historical record of ECB's macroeconomic projections. Additionally, I compare them with other four Central Banks' performances. A more exhaustive analysis on the ECB's performance was conducted recently, so I am only focusing on a more descriptive and qualitative evaluation.

For instance, Kontogeorgos and Lambrias (2019) assessed the ECB's projection errors between 2001 and 2016, by looking at criteria of optimality and rationality. Their results suggest that no significant bias has been found in the inflation projection, i.e. there is no persistent tendency to make errors in one direction. However, they also find that inflation bias has been steadily decreasing over time. In the first few years of monetary union, staff projections consistently underpredicted inflation. It was only after the Great Financial Crisis that this tendency was reversed, and forecasts started to persistently overpredict inflation. According to their results, the two periods cancel out each other, not resulting in a significant overall bias.

My hypothesis is that, following the Sovereign Debt Crisis, Central Banks' projections tend to be influenced by their mandate. A Central Bank that has a single mandate of price stability, like the European Central Bank[2], tends to present more optimistic projections, given its urge in

[2] "*Without prejudice to the objective of price stability",* the Eurosystem shall also "*support the general economic policies in the Union with a view to contributing to the achievement of the objectives of the Union."* (Treaty on the Functioning of the European Union, Article 127(1), 2012).

showing results. Whether a Central Bank with a dual mandate, like the Federal Reserve[3], may not show, in its projections, the same urgency in reaching the target in the medium-term.

The figure[4] below (figure 1) perfectly illustrates how the ECB has stubbornly predicted a rise of core inflation at least since December 2013, the first time that core inflation forecasts were made public.

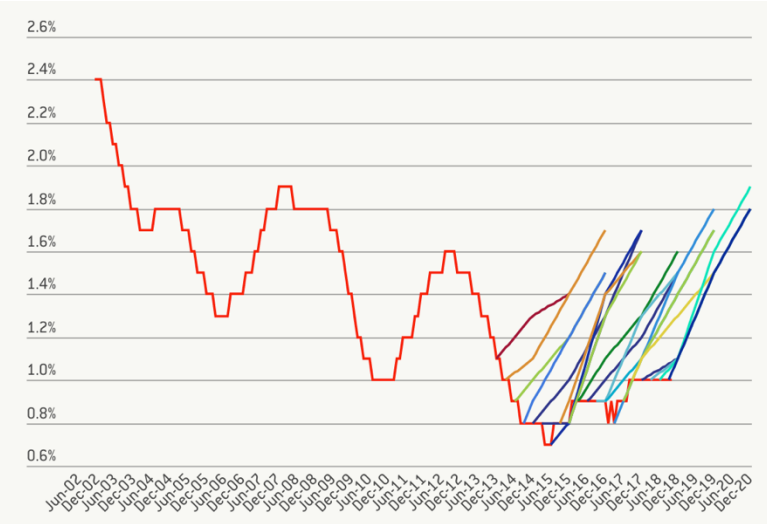

Figure 1 - ECB staff macroeconomic projections for euro-area core inflation (moving 12 months average rate of change)

Source: Bruegel

Data were collected for the European Central Bank, the Federal Reserve, the Swiss National Bank, the Risksbank, and the Bank of Canada, between 2001 and 2019.

In the early 2000s, every Central Bank publicly announced, in a quarterly-basis, its projections for that year's inflation (four-quarters ahead), and next year's inflation (eight-quarters ahead). Only later did Central Banks start to publicly present projections for inflation in two years' time (twelve-quarters ahead). Projections were majorly displayed in ranges, given their uncertainty, therefore I choose the average value of the range.

[3] "*The Federal Open Market Committee (FOMC) is firmly committed to fulfilling its statutory mandate from the Congress of promoting maximum employment, stable prices, and moderate long-term interest rates.*" (Statement on Longer-Run Goals and Monetary Policy Strategy, 2020).

[4] Actual data is the bright red line, while the remaining colorful lines show the ECB forecasts made in each quarter.

I am not particularly interested in evaluating the forecasting error in four-quarters time, since Central Banks have little room for manoeuvre in those projections. But, the eight- and twelve-quarters time forecasts can easily involve judgment, and be used to anchor consumers' expectations, contributing to the effectiveness of monetary policy in achieving price stability. According to a 2016 survey, ECB projections are taken into account by professional forecasters, as they provide benchmarks for their short- and medium-term inflation expectations. This would suggest that the ECB might have not only the motive, but also the means to influence agents' expectations by producing biased forecasts.

The following equation decomposes the Central Banks' forecasting error into two terms:

$$FE = (\pi_t - \pi^*) - (\pi_t^f - \pi^*)$$

π_t stands for realized inflation in period *t*, π^* stands for the Central Bank's target inflation, and π_t^f stands for the 8-quarters ahead projection for quarter *t*.

My hypothesis is that the first term, specially in the last six years, will tend to be large for banks with a single mandate of price stability, given their consistent but unsuccessful measures in bringing up inflation. And the second term will be much smaller, given their projections always being very optimistic and close to the two-percent target. On the contrary, for banks with a dual mandate, the first term will not be as large, nor the second will be as small.

Below, figures 2 and 3 outlay the historical behaviour of forecasting errors, for the eight-quarters horizon, for the United States and the euro area. The figures for the remaining three Central Banks can be found in the appendix.

The series in orange (series 2) correspond to the first term in the forecasting error equation decomposition, and the grey series (series 3) correspond to the second term. The blue marker records the forecasting error for that year (series 1).

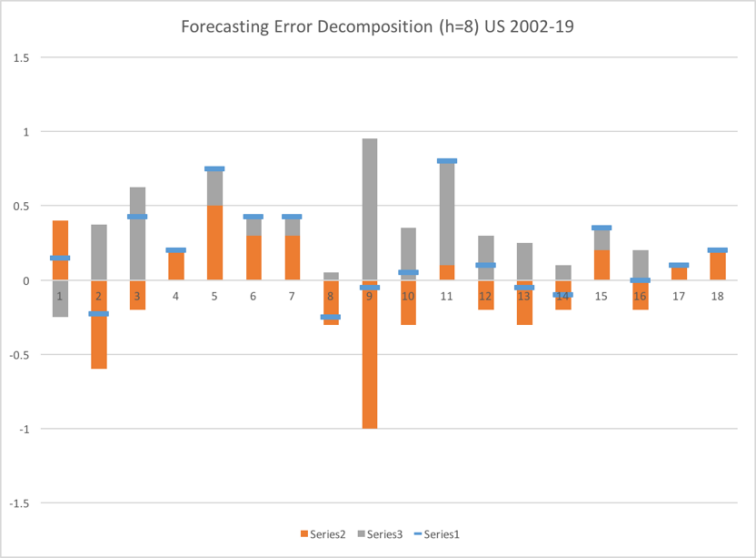

Figure 2 - Forecasting Error Decomposition (United States), 2001-19

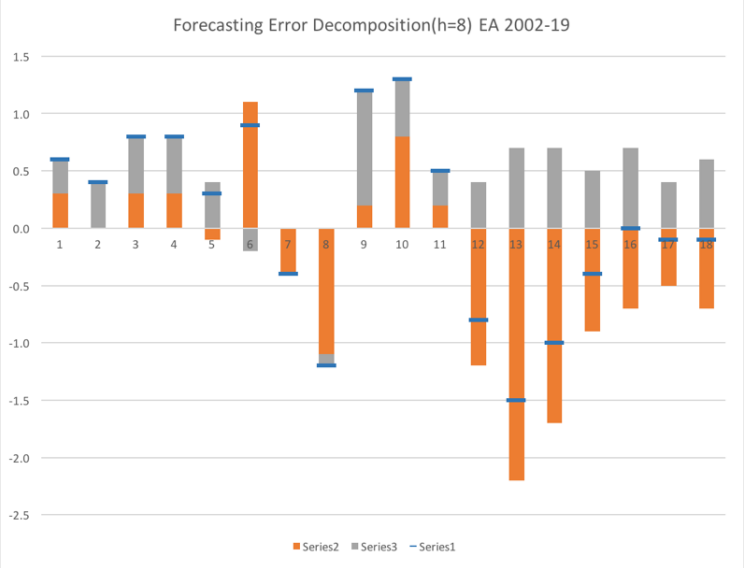

Figure 3 - Forecasting Error Decomposition (euro area), 2001-19

For the past six years, just like expected, the grey series in the ECB's graph is much larger than in the Fed's graph. This corroborates with my hypothesis of, given ECB's mandate, their forecasts seem somewhat biased. The orange series, for the last six years, confirms ECB's continuous, but failed approaches of getting inflation closer to the two percent target.

Swiss National Bank's primary objective is price stability while taking due account of economic developments. Even though their mandate is quite similar to the ECB's one, the graph does not outline the same behaviour. Their projections largely outweigh their own long-term target. The reason I find that might explain this phenomenon is their flexible inflation targeting for the short- and medium-term. Since 2007, they have adopted a more flexible interpretation of their mandate, while keeping their long-term nominal anchor – the two percent target. Their goal is not to have a two percent inflation every year, but rather an average of two percent over the years, allowing inflation to be above two percent in one year, and below two percent in the following.

The Swedish and Canadian National Banks, having a single mandate of price stability, do corroborate my hypothesis, with graphs showing quite similar patterns to the European one.

Does this consistently positive bias in ECB's projections indicate that inflation gets the largest weight in its reaction function? Before moving to the next sections, on the monetary policy reaction function of the ECB, and answering this last question, I would like to add a remark on the discussion about forecasting errors.

Forecasts provide a guidance for what is expected to happen in the economy, and what risks does the economy expects to face in the future. Based on these forecasts, individuals and firms make informed decisions. The link between individual decision making and forecasts is key for the exercise of monetary policy. However, forecasts can only be informative, if they are accurate. As such, persistent forecasting failures could potentially undermine ECB's credibility. This makes it preponderant to have a discussion on the ECB's mandate and its strategy, as it was announced by the President Lagarde earlier this year.

4. Data & Methodology

The next section discusses the sources and characteristics of the data used, as well as the methodology followed.

I gather quarterly observations for inflation forecasts, GDP growth forecasts, and yields on 10-year government bonds for five European countries, between 2001 and 2019.

Since 2015, the decision to raise, lower or leave the interest rate unchanged is made every six weeks. Before that, the Governing Council took decisions on monetary policy on a monthly basis. Given that staff projections are available every quarter I evaluate ECB's decisions on a quarterly basis. For instance, if the ECB decides to ease its monetary policy stance on January of a given year, that shows up as an 'easing' on the first quarter of that same year. Rarely are multiple policy changes made within the same quarter, and even in those cases, 98% of decisions in the same quarter go in the same direction. As such the use of quarterly data does not undermine the analysis.

The first Assets Purchase Programme was introduced in 2009. From then onwards, six more programmes have been implemented. From these, two have already been terminated, and the four remaining ones restarted purchases in the end of 2019. The introduction of a programme is assumed as an "easing" of the monetary policy stance, and the end of a programme, a "tightening" of the monetary policy stance. In the case of restarting purchases under a programme, the assumption is analogous to the introduction of such programme. Also, I include the date from which forward guidance started. I assume the latter as a monetary policy loosening.

Regarding the interest rates, the ECB makes its call on three different rates: the rate on the main refinancing operations (MRO), the rate on the deposit facility (DFR) and the rate on the marginal lending facility. I decided to focus my attention on the rate that moved closer to the EONIA rate. As the ECB states *"the EONIA rate is the starting point for the transmission*

mechanism" and *"the money market functioning is paramount for monetary policy"*. In figure 8, on the appendix, I present the path of all four rates. As it stands out, until the 9th of October of 2008, the EONIA rate stands closely to the MRO, such that I chose the MRO as the interest rate for the first eight years of my sample. After that point, the EONIA starts moving closer to the deposit facility rate (DFR) in a context of excess liquidity. So, for the remaining years of my sample I used the DFR as the interest rate set by the ECB.

Both inflation and GDP growth forecasts were extracted from ECB quarterly communications, released every March, June, September and December. I include projections for four- and eight-quarters ahead, given that the twelve-quarters ahead projection was not disclosed between 2001-2004, except for December. From the several inflation metrics, I choose headline inflation which constitutes the official inflation target.

Regarding inflation, I include the deviation of the four- and eight-quarters projections from the target ($\Delta\pi^f_{t+4}$ and $\Delta\pi^f_{t+8}$, respectively). Given that the ECB has set a clear target in the past, my hypothesis is that when the 8-quarters projection significantly deviates from the 2-percent target, the ECB will tend to change its policy direction in order to accommodate that scenario. I do not expect the 4-quarters deviation to be significant in the ECB's decision, given that headline inflation is subject to a lot of volatility from the inclusion of items such as energy and food in that measure. Therefore, it would not be sensible to have the ECB acting to every short-term deviation from the target.

In what concerns output, there is no clear target set. There are different ways to derive potential output, and estimates can differ depending on how they are derived. As such, I include the difference between projections of consecutive quarters (Δy^f_{t+4} and Δy^f_{t+8}), and not the difference between the projection and a specific target. I expect the 8-quarters projection to be quite significant. If projections deteriorate, the ECB will tend to change the direction of its policy, easing the monetary policy stance, in order to accommodate such expectations.

Endogeneity concerns may arise when explaining policy rates by projected variables. For instance, the shocks that affect GDP growth projections are not perfectly exogenous, and may affect monetary policy as well. In past research, this issue has been fixed by the use of instrumental variables, such as various lags of past inflation. Although this approach might mitigate possible endogeneity concerns, it will not fix the problem. In my research, this issue is resolved by the use of forward-looking variables, which are subject to real-time uncertainty about the future interest rate path. Such method attenuates greatly endogeneity concerns (Orphanides 2001).

I use yield spreads (ys_t) in order to gauge the integration of the euro area (EA). Data on the 10-year government bonds of Germany, Italy, Ireland, Portugal, and Spain were extracted from the ECB's statistical data warehouse, on a quarterly time basis.

German bonds are perceived as a safe asset. Some papers such as Haugh *et al*. (2009) do indeed use the Bund yield as a proxy for the risk-free rate. The remaining four countries represent that group of countries most affected by the Sovereign Debt Crisis, given their fiscal imbalances. As such, I create an artificial *yield* which equals the weighted average of the 10-year government bond yields of these four countries, according to each country's GDP.

In figure 4, I plot the curves for both the Germany yield curve and the artificial yield curve.

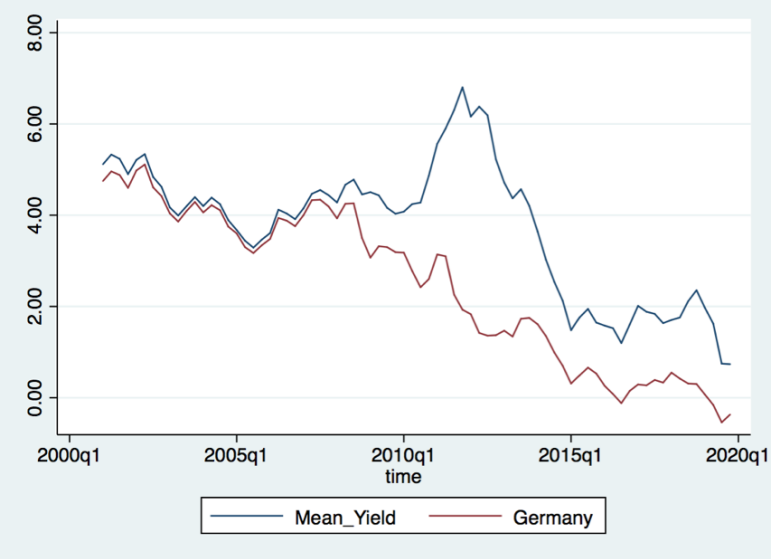

Figure 4 - Germany and Artificial Yield Curves

Lastly, I include one more variable in my model: the lagged directional change of the monetary policy choice (z_{t-1}).

Previous papers on the Central Bank's reaction function included both the lagged level of the short-term interest rate, and the lagged change of the interest rate (Carstensen 2006, Cour-Thimann and Jung 2020). The choice of these two variables derived from the smoothing behaviour that Central Banks adopt when choosing interest rates. Woodford (2003) claimed that such behaviour aimed not to disturb the markets.

However, since my research also includes unconventional measures it is more sensible to include the lagged directional change of monetary policy decisions. This way, I am better able to cast the smoothing process of monetary policy. Just like interest rates, unconventional instruments also seem to follow a smoothing process. Purchasing programmes usually last for more than four quarters, and, even when terminated, the CB reinvests its principals in the following quarters.

Let X_t represent the vector of explanatory variables available at time *t*:

$$X_t = (\Delta\pi^f_{t+4}, \Delta\pi^f_{t+8}, \Delta y^f_{t+4}, \Delta y^f_{t+8}, ys_t, z_{t-1})$$

This model outlays three possible directions that the monetary policy decision can take: "easing", "no change", and "tightening". Accordingly, I define a random variable z_t as follows[5]:

$$\boldsymbol{z_t = 1} \quad \text{if } \boldsymbol{easing}$$

$$\boldsymbol{z_t = 2} \quad \text{if } \boldsymbol{no\ change}$$

$$\boldsymbol{z_t = 3} \quad \text{if } \boldsymbol{tightening}$$

[5] "*In general, the aforementioned assignment of integer values to the categories is rather arbitrary. It is usually made as a matter of convenience, and it should be clear that such an assignment is not unique." (Moysiadis and Fokianos (2014)).*

where z_t stands for the directional change of monetary policy, which may reflect an upward change of the interest rate, or the introduction of an APP. In the ordered-probit model, the probability of $z_t = 1, 2 \text{ or } 3$ conditional on X_t is defined using the normal cumulative distribution function of random variable ε_t and an indicator variable z_t^*:

$$z_t^* = \rho_1 \Delta\pi_{t+4}^f + \rho_2 \Delta\pi_{t+8}^f + \rho_3 \Delta y_{t+4}^f + \rho_4 \Delta y_{t+8}^f + \rho_5 ys_t + \rho_6 z_{t-1} + \varepsilon_t$$

where ε_t follows a normal distribution.

The predicted probability of a given ordinal policy outcome is computed using the cumulative standard normal distribution function.

What is observed is the actual directional change of the monetary policy stance, which depends on where the latent variable is relative to a set of threshold values.

$$z_t = \begin{cases} \mathbf{1}\ if\ z_t^* < \boldsymbol{\mu_1} \\ \mathbf{2}\ if\ \boldsymbol{\mu_1} < z_t^* < \boldsymbol{\mu_2} \\ \mathbf{3}\ if\ z_t^* > \boldsymbol{\mu_2} \end{cases}$$

The ordered-probit model is estimated using the method of Maximum Likelihood, which stated heuristically, maximises the probability that the model is correct given the functional form and the observed values of the variables.

In sum, the Probit model aims to describe the directional change of the monetary policy depending on the expected level of inflation, expected economic growth, the yields spread, and the lagged directional change of monetary policy.

In the following section, I estimate the model, reporting the parameter estimates, and the marginal effects associated to each possible outcome (*easing, no change, and tightening*).

5. Results

I now present the results of the empirical ECB reaction function for different samples. Since it is not straightforward to interpret the magnitude of the coefficients in the Ordered-Probit regression, just their direction and significance, I further compute the marginal effects for each possible outcome.

The ECB's reaction function may have changed across the entirety of my sample. In order to capture possible regime changes, I report results for three time-periods: the full sample (2001-2019), the pre-crisis period (2001-2008) and the pre-ZLB period (2001-2014). Therefore, I can understand which variables were or were not significant at different points in time.

The choice of these two periods holds on Gerlach and Lewis (2014) research about the ECB's reaction function. According to their findings, the empirical reaction function switched after the Great Financial Crisis, through which the Governing Council adopted a more aggressive strategy, and later, in the latter half of 2010.

Table 1. Ordered Probit Estimates of ECB Reaction Function

	Macroeconomic Variables							
	Projected inflation (4-quarters)	**Projected inflation** (8-quarters)	**Projected GDP Growth** (4-quarters)	**Projected GDP Growth** (8-quarters)	**Yield Spreads**	**Lagged Mon. Policy Change**	**Pseudo-R^2**	**LR-statistic**
Pre-2008 (2001-2008)	17.6 (1.59)	13.2 (1.78)	**-6.21** (-1.98)	39.4 (1.83)	-48.9 (-1.47)	**9.97** (2.22)	0.82	**14.4**
Pre-ZLB (2001-2014)	**3.29** (4.32)	0.59 (0.58)	-1.69 (-1.25)	**9,77** (4.44)	-0.19 (-0.98)	**2.18** (3.25)	0.65	**33.7**
Full Sample (2001-2019)	0.71 (1.94)	**1.32** (2.00)	0.16 (0.21)	**3.04** (3.96)	-0.09 (-0.75)	**0.74** (2.34)	0.41	**37.6**

Notes: Coefficients that are statistically significant at the 5% level or lower are bold-faced. z-statistics are in parentheses. Probit estimates use the Huber-White correction. The Pseudo-R^2 is analogous to the R^2 reported in linear regression models. The LR statistic on the overall significance of the model tests the joint null hypothesis that all slope coefficients are zero. They are all significant at the 5% level.

The results from these Probit models (Table 1) support my view that projections at eight-quarters ahead influence significantly the directional change of monetary policy decisions.

Table 1 shows that the coefficients for inflation and growth projections at eight-quarters are significant and display the expected (positive) sign during the full sample, albeit being marginally significant for the period preceding the 2008 crisis.

The positive sign indicates that when the difference between the inflation forecast and the target becomes large and positive, the probability of a tightening gets bigger. This result is in line with the typically assumed reaction function of Central Banks. The same reasoning applies for the coefficient on the GDP growth. When the difference between projections across consecutive quarters is large and positive, the probability of a monetary policy tightening increases. These results are similar to the ones found earlier by Cour-Thimann and Jung (2020). And corroborate the view that in pursuing price stability, the ECB has displayed a forward-looking behaviour.

The results on the four-quarters ahead projections both for inflation and GDP growth corroborate my initial hypothesis. Given the lag between monetary policy decisions and their effect into the economy, the Governing Council does not expect to change the four-quarters projection by adopting new measures. The coefficients on these two variables are not statistically different from zero. This result holds for two of the three periods studied.

I now turn to the role of yield spreads on the reaction function of the ECB. Contrarily to my initial suggestion, and according to my results, the inclusion of yield spreads shows no significant effect on the ECB's decision. This result is robust for the three different time-frames.

After the creation of the European Monetary Union (EMU), yields on the 10-year government bonds for Germany and Southern European countries converged remarkably. Even though the spread between these two assets persisted, as the result of small differentials in fundamental risk (Pagano *et al.* 2004), it was not limiting nor affecting the mechanism of monetary policy transmission. Spreads only became a concern following the Great Financial Crisis. Investors

distrusted the ability of Southern European Countries to pay their mounting levels of debt, contributing to a self-fulfilling prophecy, and jeopardizing the mechanism of monetary policy transmission. The announcement of the Outright Monetary Transactions in 2012, Assets Purchase Programmes and other unconventional instruments were key in solving the latter, but there were other episodes regarding Portugal and Italy, in which the ECB did not take any action. Their reluctance in acting in such situations may be the reason why the coefficient on yield spreads is not significant. Even though our results seem to indicate that there is no second mandate, we are not able to claim with certainty such result. Further research should be done on that matter.

The results on the lagged change of monetary policy provide a rebuttal for previous studies. These do not confirm my hypothesis of a smoothing behaviour when deciding on the monetary policy stance. I was expecting the sign of this coefficient to be negative, implying that it is less likely that a central bank changes the direction of its monetary policy stance at two consecutive meetings. However, the sign on this variable was positive and significant at 5%, for all three time-periods. This may be the result of the Governing Council's past decisions. Once this period of continuously easing the monetary policy stance is reverted, a period of gradually tightening the monetary policy stance is expected.

I now turn to the marginal effects of my ordered-probit regression. Marginal effects show the change in probability when the independent variables increase by a unit point. By computing these I have an idea on how much does each variable contribute to the directional change of ECB's monetary policy stance.

Below, in table 2, you may find the results for two of the three possible outcomes: easing and tightening. For this latter outcome, I present five different settings. One at which all independent variables, except for the lagged monetary policy change which is equal to three, are at their mean values. A second one in which all independent variables are at their mean values, except

for the lagged monetary policy change and the projected GDP growth at eight quarters, which are equal to three and zero, respectively. An additional scenario, quite similar to the one previously stated, but at which the projected GDP growth at eight quarters is equal to 0.1. The last two scenarios compare probabilities when, conditional on the monetary policy stance having not been changed in the previous meeting, inflation projections improve from 0 to 0.1 percentage points.

Table 2. Marginal Effects

	Projected inflation (4-quarters)	**Projected inflation** (8-quarters)	**Projected GDP Growth** (4-quarters)	**Projected GDP Growth** (8-quarters)	**Yield Spreads**	**Lagged Mon. Policy Change**	**Predicted Probabilities** (at means, unless stated otherwise)
$\frac{dy}{dx}$ *Easing*	-0.28 (-1.92)	**-0.51 (-2.06)**	-0.06 (-0.22)	**-1.18 (-3.82)**	0.04 (0.75)	**-0.28 (-2.10)**	0.41
$\frac{dy}{dx}$ *Tightening*	0.15 (1.70)	0.29 (1.62)	0.04 (0.22)	**0.67 (2.01)**	-0.02 (-0.73)	0.16 (1.17)	0.13
$\frac{dy}{dx}$ *Tightening* $\Delta y_{t+8}^{f} = 0$	0.22 (1.87)	0.41 (1.89)	0.05 (0.22)	**0.93 (2.52)**	-0.02 (-0.75)	0.22 (1.43)	0.24
$\frac{dy}{dx}$ *Tightening* $\Delta y_{t+8}^{f} = 0.1$	0.26 (1.93)	**0.48 (2.02)**	0.06 (0.22)	**1.11 (0.03)**	-0.03 (-0.76)	0.27 (1.72)	0.34
$\frac{dy}{dx}$ *Tightening* $\Delta \pi_{t+8}^{f} = 0$	**0.12 (2.53)**	0.22 (1.15)	0.02 (0.22)	**0.52 (2.13)**	-0.02 (-0.80)	0.12 (1.61)	0.09
$\frac{dy}{dx}$ *Tightening* $\Delta \pi_{t+8}^{f} = 0.1$	**0.14 (2.62)**	0.26 (1.12)	0.03 (0.22)	**0.62 (2.09)**	-0.02 (-0.80)	0.15 (1.63)	0.12

Notes: Marginal effects for the outcome "easing" are computed at the means of the independent variables, except for the lag on the monetary policy change which is equal to one. Marginal effects for the outcome "tightening" are computed for five different settings. Coefficients that are statistically significant at the 5% level or lower are bold-faced. z-statistics are in parentheses.

Results, in table 2, show that the change between output projections, at eight-quarters time, is always statistically significant, regardless of the scenario chosen. On the contrary, the coefficients on inflation projections are not always statistically significant. Additionally, by looking at the magnitude of the coefficients, it becomes clear that output growth projections seem to hold the largest weight in what regards monetary policy decisions. This result contradicts our initial suggestion of inflation being ECB's major concern. Their consistent concern in having projections always *below, but close to two* percent, for the past six years, seemed to indicate that the ECB was solely concerned with inflation. But these results provide a rebuttal for such statement.

I am now focusing on the last four rows in table 2 above. There is a first scenario in which we compare the probability of tightening when output projections improve from 0 to 0.1 percentage points, conditional on the previous decision having been tightening. Results state that the probability of tightening increases by 10 percentage points, when output projections improve.

The second scenario compares the probability of tightening when inflation projections improve from 0 to 0.1 percentage points, conditional on the monetary policy stance having not been changed in the previous meeting. As we can see, as inflation projections improve from 0 to 0.1 percentage points, the probability of tightening increases by 3 percentage points.

I present four additional scenarios in the appendix (table 4), concerning the probability of easing. Those four scenarios are all conditional on the previous decision having been not changing the monetary policy stance. Then, I compare the difference in probabilities if inflation projections deteriorate by 0.1 percentage points, and if output growth projections deteriorate by

the same amount. Results show that, if inflation projections deteriorate, the probability of easing increases by 2 percentage points. Furthermore, if output growth projections deteriorate, the probability of easing increases by 6 percentage points. Once again, output projections seem to be the most significant variable, and to hold the largest weight in what concerns ECB's monetary policy decisions.

Summing up, results on the direction and significance of the coefficients confirm previous studies on the reaction function of the ECB. When projections for both inflation and output improve, the ECB is more likely to tighten the monetary policy stance. Also, coefficients on yield spreads were not significant at any of the three time-frames studied. The reasoning behind such result may lay on the reluctance of ECB in acting in situations involving Portugal and Italy. However, more research should be done on this matter, in order to evaluate whether the ECB has or has not a dual mandate. Data is quite limited, given that unconventional instruments were only introduced following the Great Financial Crisis. Lastly, the marginal effects for different outcomes indicate that GDP growth projections seem to hold the largest weight in monetary policy decision making. Such result helps to answer one of my research questions, on whether the ECB was solely focused on inflation, or was inflation the most important variable in ECB's reaction function. Results do not confirm such statement.

6. Conclusion

In this research, the monetary policy reaction function of the ECB is estimated for three different time frames, in order to capture possible differences in ECB's decision making, throughout the last 19 years. I resort to an ordered-probit model given the discrete behaviour of monetary policy decisions. Furthermore, given that interest-rate setting is no longer the only monetary policy instrument used by CBs, and there is no commonly accepted way to convert APP or Forward Guidance into interest rates, I only focus on the directional change of monetary policy decisions.

Results confirm ECB's forward-looking behaviour. Changes in the monetary policy direction seem to respond to staff projections both for inflation and output at eight-quarters time. Projections at four-quarters time seem to not be as important in decision making. Also, given that I use headline inflation, and this latter is subject to a lot of volatility, it is not expectable that the ECB responds to each single forecasts' deviation from the target.

Results do not confirm the existence of a second mandate of financial stability. Coefficients on yield spreads are not statistically significant at any time-frame. The use of unconventional programmes, albeit being key in guaranteeing financial markets' stability, seems to be aiming at price stability.

Finally, I analyse ECB's forecasting errors, and conclude that their projections have been consistently biased for the last six years. This could be the result of ECB being solely focused on inflation, but only in public communication. In fact, results on marginal effects, do not confirm that the ECB's sole focus is on inflation. On the contrary, GDP growth projections hold the largest weight in ECB's monetary policy decisions.

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Appendix

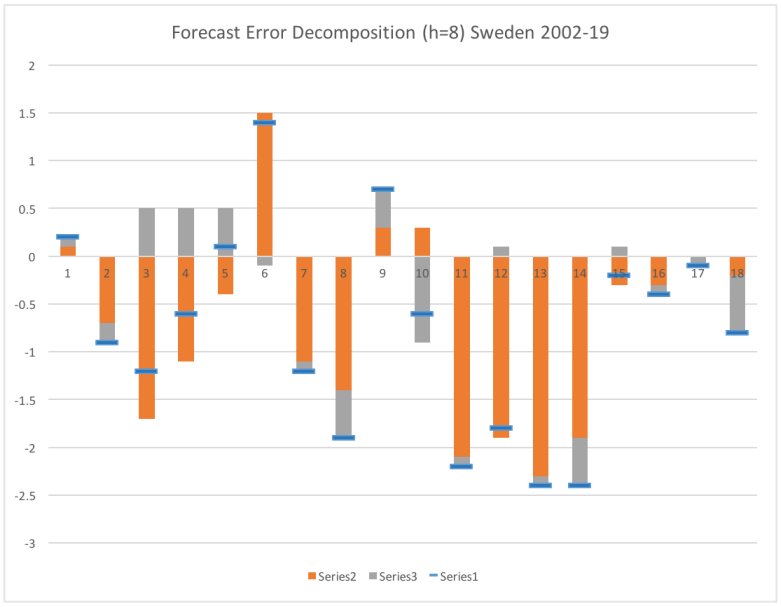

Figure 5 - Forecasting Error Decomposition (Sweden), 2001-19

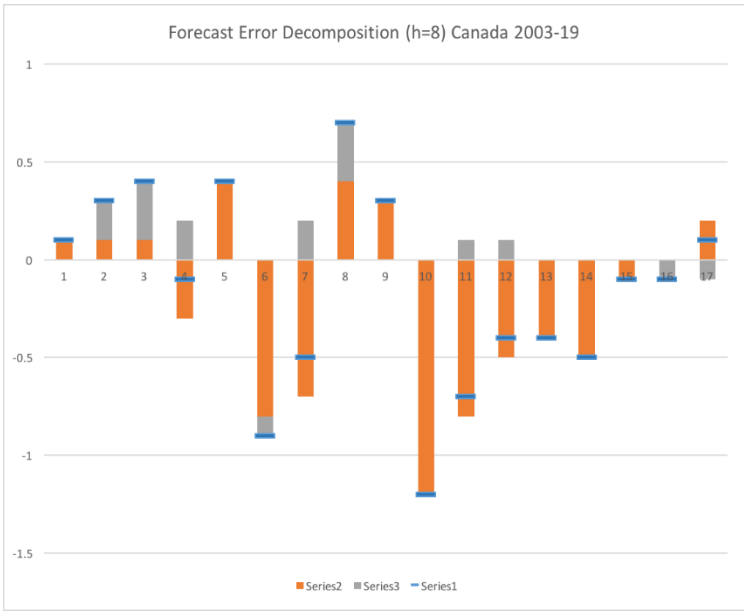

Figure 6 - Forecasting Error Decomposition (Canada), 2001-19

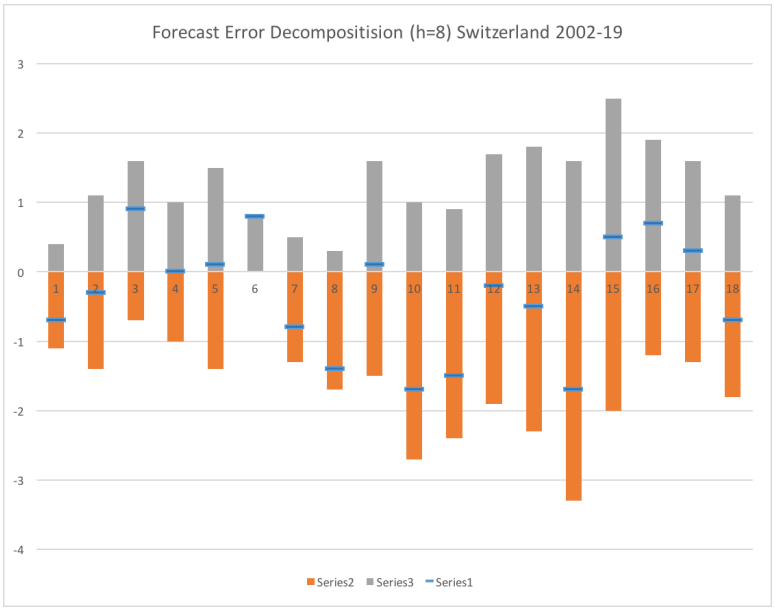

Figure 7 - Forecasting Error Decomposition (Switzerland), 2001-19

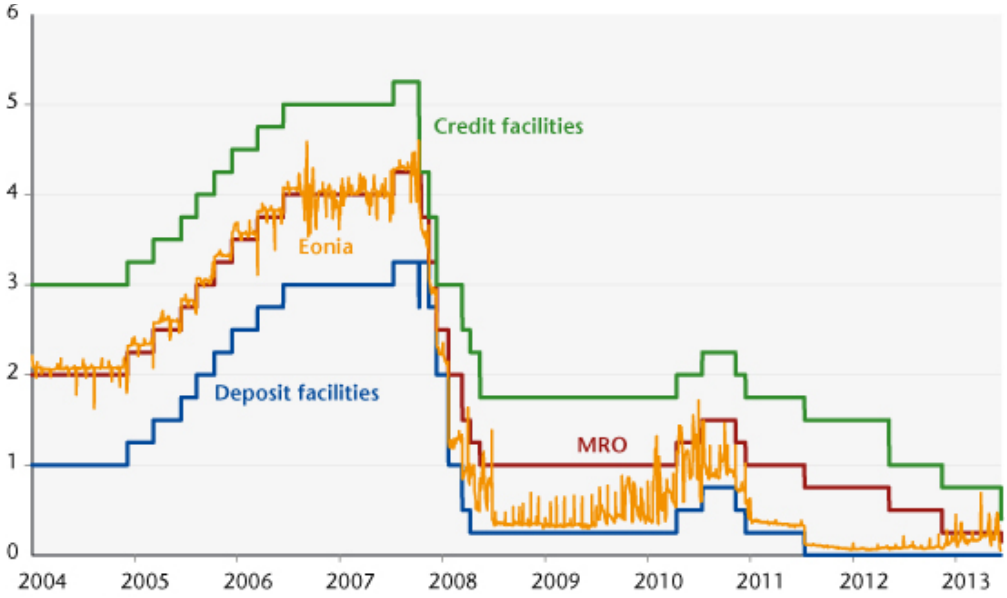

Figure 8 - Main ECB rates and EONIA rate

Source: ECB

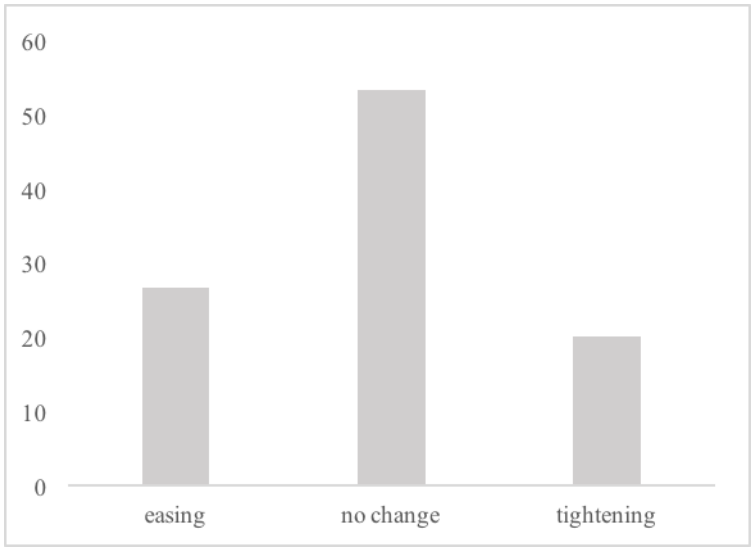

Figure 9 - Monetary Policy Decisions, quarterly (2001 – 2019)

Table 3. Description of the Dataset

Variable	**Source and Description**
Interest rates: - MRO rate - DFR	ECB statistics (Statistical Data Warehouse) - FM.B.U2.EUR.4F.KR.MRR_MBR.LEV - FM.B.U2.EUR.4F.KR.DFR.LEV
ECB staff forecasts (for inflation and growth)	Hand collected from the ECB website (real-time)
GDP for Germany, Italy, Ireland, Spain and Portugal	Eurostat
Yield Spreads: - Germany 10-year government bonds - Italy 10-year government bonds - Ireland 10-year government bonds - Spain 10-year government bonds - Portugal 10-year government bonds	ECB statistics (Statistical Data Warehouse) - IRS.M.IT.L.L40.CI.0000.EUR.N.Z - IRS.M.DE.L.L40.CI.0000.EUR.N.Z - IRS.M.IE.L.L40.CI.0000.EUR.N.Z - IRS.M.ES.L.L40.CI.0000.EUR.N.Z - IRS.M.PT.L.L40.CI.0000.EUR.N.Z

Table 4. Marginal Effects

	Projected inflation (4-quarters)	**Projected inflation** (8-quarters)	**Projected GDP Growth** (4-quarters)	**Projected GDP Growth** (8-quarters)	**Yield Spreads**	**Lagged Mon. Policy Change**	**Predicted Probabilities** (at means, unless stated otherwise)
$\frac{dy}{dx}$ *Easing* $\Delta y_{t+8}^{f} = 0$	-0.12 (-1.61)	-0.21 (-1.81)	-0.03 (-0.21)	**-0.49** **(-3.18)**	0.02 (0.72)	**-0.12** **(-2.53)**	0.09
$\frac{dy}{dx}$ *Easing* $\Delta y_{t+8}^{f} = -0.1$	-0.17 (-1.66)	-0.31 (-1.93)	-0.04 (-0.21)	**-0.71** **(-3.17)**	0.02 (0.74)	**-0.17** **(-2.70)**	0.15
$\frac{dy}{dx}$ *Easing* $\Delta \pi_{t+8}^{f} = 0$	-0.09 (-1.07)	**-0.17** **(-2.98)**	-0.02 (-0.21)	-0.39 (-1.70)	0.01 (0.66)	-0.09 (-1.58)	0.07

$\frac{dy}{dx}$ *Easing* $\Delta\pi^{f}_{t+8} = -0.1$	-0.11 (-1.21)	**-0.21** **(-2.85)**	-0.03 (-0.21)	**-0.47** **(-2.07)**	0.01 (0.69)	-0.11 (-1.89)	0.09